# FLEXIBLE SHAFT FOR GAS TURBINE ENGINE

## CLAIM OF PRIORITY

This patent application is a continuation-in-part of, and claims priority from U.S. application Ser. No. 11/481,112 filed on Jul. 5, 2006, which is incorporated by reference in its entirety.

## BACKGROUND OF THE INVENTION

1. Technical Field

This disclosure relates generally to shafts within a gas turbine engine in general, and to flexible shafts used within a gas turbine engine having an epicyclic gear train in particular.

2. Background Information

Gas turbine engines typically employ an epicyclic gear train connected to a turbine section of the engine, which is used to drive the fan section. In a typical epicyclic gear train, a sun gear receives rotational input from a turbine shaft through a compressor shaft. A carrier supports intermediate gears that surround and mesh with the sun gear. A ring gear surrounds and meshes with the intermediate gears. In arrangements in which the carrier is fixed against rotation, the intermediate gears are referred to as "star" gears and the ring gear is coupled to an output shaft that supports the turbo fan. In arrangements in which the ring gear is fixed against rotation, the intermediate gears are referred to as "planetary" gears and the carrier is coupled to the output shaft that supports the turbo fan.

During operation, forces and torque transferred through the epicyclic gear train can create tremendous stresses within the gear train components, making them susceptible to breakage and wear, even under ideal conditions. These stresses can be exacerbated in instances where there is an axial misalignment or shift between the sun gear and the shaft. Such axial misalignments and shifts can be induced by imbalances in rotating hardware, manufacturing imperfections, and transient flexures of the shafts and support frames due to aircraft maneuvers. Consequently, there is a need in the art for a flexible shaft that can accommodate such axial misalignments and shifts, while still maintaining adequate torsional rigidity to drive the epicyclic gear train.

## SUMMARY OF THE DISCLOSURE

According to a first aspect of the invention, a shaft for a gas turbine engine is provided that includes a first shaft section, a second shaft section, a first flexible linkage, and a second flexible linkage. The first shaft section extends between a forward axial end and an aft axial end along a first axial centerline. The second shaft section extends between a forward axial end and an aft axial end along a second axial centerline. The first flexible linkage includes a bridge section connected to a first diaphragm and a second diaphragm. The first diaphragm is connected to the aft axial end of the first shaft section. The second diaphragm is connected to the forward axial end of the second shaft section. The second flexible linkage includes a diaphragm and a hub. The second flexible linkage diaphragm cantilevers radially outwardly from an inner radial end to an outer radial end, and is connected to the aft axial end of the second shaft section. The hub is connected to the outer radial end of the second flexible linkage diaphragm, and includes an engine shaft coupling connected to the hub.

According to another aspect of the present invention, a gas turbine engine is provided that includes a fan section, an engine shaft, and a flexible shaft for a gas turbine engine. The flexible shaft includes a first shaft section, a second shaft section, a first flexible linkage, and a second flexible linkage. The first shaft section extends between a forward axial end and an aft axial end along a first axial centerline. The second shaft section extends between a forward axial end and an aft axial end along a second axial centerline. The first flexible linkage includes a bridge section connected to a first diaphragm and a second diaphragm. The first diaphragm is connected to the aft axial end of the first shaft section. The second diaphragm is connected to the forward axial end of the second shaft section. The second flexible linkage includes a diaphragm and a hub. The second flexible linkage diaphragm cantilevers radially outwardly from an inner radial end to an outer radial end, and is connected to the aft axial end of the second shaft section. The hub is connected to the outer radial end of the second flexible linkage diaphragm, and includes an engine shaft coupling connected to the hub.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial cross-sectional view of a front portion of a gas turbine engine illustrating a fan section, an epicyclic gear train, a compressor shaft and a compressor section.

FIG. **2** is a cross-sectional view of the epicyclic gear train and the compressor shaft shown in FIG. **1**.

FIG. **3** is a cross-sectional view of another embodiment of the epicyclic gear train and the compressor shaft shown in FIG. **1**.

FIG. **4** is a cross-sectional view of an aft portion of the compressor shaft shown in FIG. **3**.

FIG. **5** is an end view of the epicyclic gear train taken along line **3**-**3** in FIG. **2** with a pair of star gears shown in phantom in an installation position.

FIG. **6** is an enlarged view of a portion of the epicyclic gear train shown in FIG. **5** with a sun gear and star gears shown in phantom.

FIG. **7** is an enlarged view of a portion of the epicyclic gear train shown in FIG. **2**.

FIGS. **8**A and **8**B diagrammatically illustrate an axial shift in the compressor shaft shown in FIG. **3**.

FIGS. **9**A and **9**B diagrammatically illustrate an axial misalignment in the compressor shaft shown in FIG. **3**.

## DETAILED DESCRIPTION OF THE INVENTION

A portion of a gas turbine engine **10** is shown schematically in FIG. **1**. The turbine engine **10** includes a fixed housing **12** that is constructed from numerous pieces secured to one another. A compressor section **14** having compressor hubs **16** with blades are driven by an engine shaft **15** about an axis A. A fan **18** is supported on a fan shaft **20** that is driven by a compressor shaft **24**, which supports the compressor hubs **16**, through an epicyclic gear train **22**.

Referring to FIGS. **2** and **3**, the compressor shaft **24** includes one or more annular shaft sections **106**, **108** and one or more annular flexible linkages **110**, **112**. In the specific embodiment in FIG. **3**, the compressor shaft includes a first shaft section **106**, a second shaft section **108**, a first flexible linkage **110**, and a second flexible linkage **112**.

Now referring to FIG. **3**, each shaft section **106**, **108** extends axially (e.g., parallel to the axis A) between a forward end **114**, **116** and an aft end **118**, **120**. The first shaft section **106** has a wall thickness **122**, a length **124**, and an outer radius **126**. The second shaft section **108** has a wall thickness **128**, a